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THE INTERNATIONAL GEOSPHERE/ BIOSPHERE PROGRAM—1984

REPORT

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LETTER OF SUBMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC, March 4, 1985.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: The Subcommittee on Space Science and Applications held two days of hearings in September 1984 on the International Geosphere/Biosphere Program (IGBP). This would be an international, interdisciplinary study of the earth as a system and the man-induced and natural changes in that system.

IGBP will involve many Federal agencies including at least NASA, NSF, NOAA, EPA, and the Departments of Energy, Agriculture and Interior. One purpose of this report is to provide a summary of the present status of IGBP to the broad range of interested persons in those agencies and in their Congressional oversight committees.

Mr. Chairman, I commend this report to you and the other Members of the Committee.

Sincerely,

BILL NELSON,
Chairman.

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I. CONCLUSIONS AND RECOMMENDATIONS

1. Overall. The International Geosphere/Biosphere Program is a promising concept needing considerably more definition and such efforts are underway. IGBP could contribute greatly to our understanding of the Earth as a system, and thus to dealing with problems such as acid rain and the CO2 greenhouse effect. A great deal of organizational coordination will be necessary because if IGBP is to be successful, it will be both international and interdisciplinary. Further, in the U.S. it will involve several Federal agencies as well as universities. Reaching a consensus on the scientific scope of IGBP may be difficult. Nevertheless, the Committee sees no reason why a well-defined program cannot be achieved and hopes that the IGBP will move ahead along the general lines that have been proposed.

2. National Academy of Science. The steps taken by the National Academy of Sciences to form a U.S. national program and to stimulate the International Council of Scientific Unions to begin developing an international program are wise. The Committee encourages the Academy to continue its efforts, in particular the efforts of its Committee on an International Geosphere/Biosphere Program.

3. Earth System Sciences Committee. NASA should be prepared to participate in IGBP when it becomes an operating program. The NASA Advisory Committee on Earth System Sciences is taking steps to develop a scientifically sound "Global Habitability" program which would be NASA's contribution to IGBP. Realizing the broad, interdisciplinary nature of both Global Habitability and IGBP, the Earth System Sciences Committee (ESSC) is reaching out to other agencies as well. The Committee encourages these activities of the ESSC.

4. NASA. The Committee encourages NASA to continue its activities in support of the development of IGBP, and in particular recommends the further development of its Global Habitability program.

In the past, the Committee has recommended that NASA develop a Global Resources Information System.[1] The Committee was therefore pleased to hear testimony on NASA's initiative to cooperate with United Nation's Environmental Program (UNEP) to develop the Global Resources Information Data Base System (GRID). The Committee recommends that NASA continue this effort and requests that it be kept informed of developments.

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[1]House Report 98-629, p. 32.

NASA will be conducting several research and development activities that could contribute to IGBP. The Committee therefore recommends that particularly in planning its research on remote sensing and Earth observation and in developing its Space Station, NASA explicitly consider the data needs of the IGBP program.

5. Other Federal Agencies. If the U.S. national program for IGBP is to be a success, several Federal agencies will have to contribute to it. The main contributors should be NASA, NOAA, and NSF. NOAA's research programs virtually encompass the scope of IGBP and its operational satellite and data programs represent existing assets critical to practical implementation of IGBP. Several of NOAA's missions (such as weather prediction) could be aided by information developed by IGBP. The NSF is the Federal agency through which the university research community can best contribute to IGBP. Mission agencies, such as the Department of Energy, EPA, Department of Agriculture, and Department of Interior, potentially can both contribute to and benefit from IGBP. For example, should IGBP develop a better understanding of the global carbon cycle, this understanding would surely contribute to DOE's policy decisions regarding the CO2 greenhouse effect.

The Committee recommends that Federal agencies support the development of IGBP. For example, NOAA should consider the data needs of IGBP in planning future environmental data and information services. NSF should take appropriate steps to involve the basic research community in IGBP. Mission agencies should support the development of IGBP insofar as it can assist them in accomplishing their missions.

II. INTRODUCTION

The International Geosphere/Biosphere Program (IGBP) is not yet truly a program, but at this point only a proposal for such a program, so that our description of IGBP is necessarily tentative. The basic concept calls for a holistic study of the Earth-as-a-system on an interdisciplinary and international basis in an effort to understand global changes in the Earth's environment and in its biological systems.

If this proposal should reach fruition, it would in many ways follow patterns set twenty-five years ago in the International Geophysical Year (IGY). In the IGY -- an international global program which was an outstanding success -- scientists from 67 nations worked together. During its year and a half duration, coordinated measurements were taken from pole to pole. These measurements, together with the analysis that followed, have greatly improved our understanding of the Earth.

An important difference between IGY and IGBP is the inclusion in IGBP of ecological and biological studies which were virtually neglected during the IGY. In addition, IGBP would focus more on interdisciplinary and multidisciplinary activities than was the case for IGY.

The Committee on Science and Technology has maintained an interest in such global international and integrative programs which can contribute to the welfare of mankind by helping us better understand the world in which we live. A specific example of earlier Committee involvement is the National Climate Program Act of 1978 (Public Law 95-367), which was developed in the Committee. Also, more generally, the Committee has consistently supported the applications of the United States civilian space program "for the benefit of all mankind".[2]

At the August 1982 United Nations Conference on the Exploration and Peaceful Uses of Outer Space (Unispace '82) held in Vienna, the United States (represented by the Administrator of NASA), revealed a "Global Habitability" initiative. The purpose of this proposed program was to understand better the Earth's ability to support life by studying its geochemical cycles and climate. NASA's proposal was the outgrowth of a workshop on "Global Change: Impacts on Habitability, A Scientific Basis for Assessment" in June of 1982 and a workshop report submitted to NASA on July 7, 1982 formed the basis for the initiative presented in Vienna. Thus, there was very little time before the Unispace meeting, which began on August 9, 1982, for NASA to do the coordination necessary to advance such an ambitious program. The initiative was not well received at Vienna, nor did it have sufficient

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[2]Section 102(a) of Public Law 85-568, The National Aeronautics and Space Act of 1958.

backing within the Administration (because it had been only quickly and superficially coordinated with other agencies). Unfortunately, there existed at the time a perception in several offices that NASA had proposed Global Habitability merely as a cover for some of its existing applications programs. Since the conference, the Agency has had to struggle to keep the concept alive.

In April of 1983, the Committee on Science and Technology, in its report accompanying the Fiscal 1984 NASA authorization bill, requested NASA to do a study (to be conducted through the National Research Council of the National Academies of Science and Engineering) of the scientific connections and importance of Sun/Earth interactions. The Committee wanted this study to be broad in scientific scope and to involve all relevant Federal agencies. NASA has not responded completely satisfactorily to this request, although they have made several partial responses. As will be seen below, it appears that one of NASA's internal advisory committees is taking steps in the direction the Committee had requested.

At the same time but totally independent of the Science and Technology Committee, forces were moving within the National Academy of Sciences to advance a program somewhat similar to the Committee concept. In July of 1983, the National Research Council held a workshop, "Toward an International Geosphere/Biosphere Program, A

Study of Global Change". The workshop reached a majority conclusion that an International Geosphere/Biosphere Program conducted under the International Council of Scientific Unions (ICSU), could provide an effective vehicle for coordinating global measurements, exploiting new observation technologies, implementing improved data management capabilities, and placing proper emphasis on mathematical modeling.[3] The workshop contrasted IGBP with the relatively short-lived IGY: IGBP should be planned during the remainder of this decade, should reach maturity in the 1990s, and should continue for perhaps several decades. The workshop urged that national organizations immediately begin planning and that the various national plans be brought forward at the ICSU general assembly in September of 1984. Finally, the workshop recognized the need for IGBP to work with existing national and international programs.

Subsequently, the National Academy of Sciences established a Committee for the International Geosphere/Biosphere Program, chaired by Dr. John A. Eddy. In February of 1984, Dr. Eddy testified before the Committee on Science and Technology to describe how his committee would attempt to develop a U.S. national program for IGBP.[4]

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[3]Toward an International Geosphere/Biosphere Program, National Research Council, National Academy Press, Washington, DC, 1983.

[4]1985 NASA Authorization, Hearings, Committee on Science and Technology, 98th Congress, No. 84, Vol. II, February/March 1984, p. 517 ff.

In response to Dr. Eddy's testimony and the various workshops, and because of a general feeling of need for a synoptic study of the Earth, the Committee decided that IGBP warranted its support. Accordingly, the Committee addressed recommendations to four agencies in reports accompanying four bills that moved through the Committee in early 1984. These were the Fiscal Year 1985 authorizations for NASA[5], for the National Science Foundation[6], and for the Department of Energy[7], and also in the Land Remote-Sensing Commercialization Act of 1984 (where the language was addressed to NOAA).[8] In each case, with virtually identical language, the Committee urged the agency addressed to support IGBP. For example, the language addressed to NOAA in the Land Remote-Sensing Commercialization Act was as follows:

> "The Committee has examined the research programs of the National Oceanic and Atmospheric Administration in the context of this new mandate and has concluded that these programs have the potential to make major contributions to IGBP. It will be crucial to draw upon NOAA's strength

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[5]H.R. 5154, House Report No. 98-629.

[6]H.R. 4974, House Report No. 98-642.

[7]H.R. 5244, House Report No. 98-686.

[8]H.R. 5155, House Report No. 98-647.

> in formulating the scientific goals of IGBP and in defining the United States role in the program. Resources spent by NOAA in these areas will achieve a substantially greater value if coordinated with an overall observation and research effort.
>
> The Committee urges NOAA to cooperate with other Agencies to support efforts to define IGBP's scope, objectives, and future plans. The Committee looks with anticipation to the international acceptance of either IGBP or a meaningful alternative framework within which resources can be focused.[9]

As a step toward the realization of IGBP, a Symposium on Global Change was organized at the September meeting of ICSU in Ottawa. Scientists from 14 nations presented papers on various aspects of IGBP such as the atmosphere/ocean interaction, modeling of the biosphere, and solar-terrestrial physics. The United States, Western Europe, the Soviet Union, China, Japan, and Australia were represented. Because the symposium was scheduled for September 25 and the Congressional adjournment target was October 4, the Committee felt that there would not be adequate time after the symposium for the Committee to hold hearings to receive a report on its results. The Committee also believed that it would be beneficial to hold hearings ahead of the symposium to ensure that the

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[9]House Report 98-647, page 41.

United States delegation and the Federal agencies that had been advised to support IGBP were working together to prepare for the symposium.

Accordingly, the Committee scheduled hearings on September 13 and 14, 1984. The total testimony with some supporting material is printed separately.[10] This report provides a summary of that testimony.

[10] International Geosphere/Biosphere Program 1984, Hearings, Committee on Science and Technology, 98th Congress, No. 118, September 12 and 13, 1985.

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III. WITNESSES

On the first day of hearings, September 12, the Committee heard testimony from Dr. Francis Bretherton and Dr. Thomas Malone, both of whom are eminently qualified to comment on IGBP.

Dr. Thomas Malone

Dr. Malone is currently serving as Scholar-In-Residence at Saint Joseph's College in West Hartford, Connecticut. He is also a Natural Sciences Fellow at Resources for the Future in Washington, but more importantly for these hearings, he testified as one of the co-convenors of the (ICSU) Symposium on Global Change held in Ottawa. Dr. Malone was educated as a meteorologist and continues a long, distinguished career involving a great deal of international activity. For example, he has been International Secretary of the National Academy of Sciences and Vice-President and Treasurer of the International Council of Scientific Unions. He helped organize both the IGY and later the Global Atmospheric Research Program. He has been on a great many advisory committees for science and technology and National Academy Committees related to atmospheric science, geophysics, and space applications.

Dr. Francis Bretherton

Dr. Bretherton is Senior Scientist at the National Center for Atmospheric Research in Boulder, Colorado, but testified principally as Chairman of the NASA advisory committee on Earth Systems Sciences. The charter of this committee is to develop a NASA research program which would treat the Earth as an integrated system. Dr. Bretherton has been trained in meteorology and fluid dynamics and has a long and distinguished career in atmospheric research. He has served on many advisory committees, including the Committee on Atmospheric Science of the National Academy of Sciences.

On the second day of the hearings, the Committee invited witnesses from each of the four agencies to which the Committee had addressed report language encouraging their support for IGBP.

National Aeronautics and Space Administration

First to testify was Dr. Shelby G. Tilford, Director of the Earth Science and Applications Division at NASA. Because of its commitment to develop and launch a series of satellites generating data about the Earth, its atmosphere and oceans, NASA clearly will be a major participant, not only in the U.S. national program, but in any international program that develops. Most of these satellites will be flown under programs for which Dr. Tilford is responsible.

National Oceanic and Atmospheric Administration

NOAA was represented by Dr. John H. McElroy, Assistant Administrator for Environmental Satellite, Data, and Information Services in NOAA. Dr. McElroy is responsible for the weather satellites which would be important contributors of data to IGBP and he has been involved in many of the existing international research programs with which IGBP must interact and coordinate.

National Science Foundation

Dr. Albert L. Bridgewater, Acting Assistant Director for Astronomical, Atmospheric, Earth and Ocean Sciences at the National Science Foundation, represented his agency. Clearly, much of the basic research that will turn data into scientific information would have to be conducted at universities funded by the National Science Foundation, and therefore their support of IGBP is important.

Department of Energy

Finally, Dr. Alvin W. Trivelpiece, Director of the Office of Energy Research at the Department of Energy represented that Agency which is not only a user of the kind of information that IGBP would generate but also funds a great deal of research which would contribute to the IGBP. The Department of Energy is responsible for understanding the effects of energy technologies (such as the

burning of coal which contributes carbon dioxide to the atmosphere) and has been quite supportive of the research programs needed to explicate these effects. Thus, the Department has a useful institutional perspective as both a user and generator of information.

IV. SUMMARY OF TESTIMONY BY ISSUE

The Subcommittee asked the witnesses to address several questions. The following sections summarize the testimony around these questions.

1. Organizationally, what is IGBP now? What could or should it become?

Dr. Malone stated that the IGBP is something between an idea and a program. He referred to it as a "proposal" and went on to say that ... "At Ottawa, the decision will not be made to adopt it as a program, the decision that we expect will be authorization to proceed with the planning." Dr. Tilford also identified the IGBP as a proposal of the National Research Council, National Academy of Sciences to be conducted under the auspices of the ICSU. It was also made clear, especially by the testimony of Dr. McElroy and Dr. Bretherton, that the proposed IGBP would have considerable overlap with the "Global Habitability" concept previously advanced by NASA and with other programs such as the World Climate Research Program.

There are several fundamental organizational questions, such as the one posed by Dr. Bretherton: "How best to structure the long-term observations which are essential for understanding changes in the Earth system over decades or longer?" This is particularly important because much of the needed information

would be derived from data originally obtained for short-term operational purposes -- for example, weather data. Therefore, it would be very important, according to Dr. Bretherton, for IGBP to "find ways to work closely with such operations and influence their priorities, for small changes would bring large benefits" for the IGBP. Dr. Tilford also pointed out that the study "will require an interdisciplinary research program with international cooperation and participation."

Dr. Bretherton was more specific in describing what must be achieved through the international organizations. "First of all, a community of objectives, and secondly, the free exchange of information and data, and only thirdly ... cost sharing."

Dr. Bretherton made it clear that in order to understand the Earth and how it functions as a complete system, we cannot artifically circumscribe ourselves by traditional scientific disciplinary, institutional, or national patterns of thought. The problem "we are engaged in is very much one of how do we break out of those bounds, because the problems we are dealing with absolutely require us to do so." Dr. Malone agreed that the program must be multi-disciplinary and described this as a "difficulty", because "scientists by tradition are quite comfortable working in a discipline." He made it clear that a multi-disciplinary program "flies in the face of the reward system and the scientific tradition". Therefore, he pointed out, the institutions which will support IGBP have their own ways of doing things with which they are very

comfortable and in which they have traditionally operated, "so that both the way of thinking of scientists and the way of thinking of institutions is going to have to be altered ..."

In summary, it seems that the organizational status of IGBP is that of a proposal and that only outlines of its eventual shape can be seen. However, if the program is to be successful, it will certainly be both international and interdisciplinary. This poses a challenge. Organizing either an international disciplinary program or a national interdisciplinary program is difficult. The compounded task represented by IGBP will require skill and patience for its accomplishment.

2. Scientifically, what is IGBP now? What could or should it become?

Drs. Malone and Bretherton agreed on the broad scientific goals of the IGBP program: Dr. Bretherton testified, "as an advocate of a strategy to better understand the planet Earth, using a program of global observations, including a strong U.S. initiative embedded in an international effort." Dr. Malone spoke of needing to develop "an understanding of the natural processes in the sun-earth system" in order to be able to understand both natural and anthropogenic changes.

Dr. Malone testified that specific objectives would be formulated over the next two years and then pursued through a set of sharply focused activities during the 1990s. Dr. Bretherton made essentially the same point but added, "it is critical that the issues be first examined broadly enough in ways which are relatively unconstrained by traditional institutional or disciplinary boundaries." Dr. Bridgewater, testifying for the National Science Foundation, noted this lack of specific objectives and suggested the lack of "a clear or present consensus in the U.S. scientific community as to the objectives of an IGBP or the scientific approaches that should be followed to achieve those objectives." On the other hand, Dr. Bretherton gave his opinion that "those differences are minor at this stage and ... more concerned with the history and the background of the group ... discussing rather than the real substantive pieces of the program." Dr. Bretherton made the point that achievement of an effective international consensus on scientific objectives will be difficult, yet will be "greatly eased" by a strong and well-conceived U.S. national program as a nucleus.

Dr. Tilford observed that both the scientific community and NASA realize that in order to study the processes which lead to biological changes on Earth on a global scale, it is necessary to study the Earth as an integrated system, "because the land, the atmosphere, the oceans, and the biosphere are coupled on timescales of a decade or longer". Dr. Tilford pointed out that because IGBP is not yet defined, it is somewhat difficult to describe the exact

relationship between IGBP and NASA programs. Nevertheless, it is clear that several NASA programs will be involved, such as geodynamics and geology, space plasma physics, solar physics, and NASA's land, ocean, atmosphere, and climate programs.

NASA's Earth Systems Sciences Advisory Comittee is chaired by Dr. Bretherton, he described their work as follows:

> "The Earth Systems Sciences Committee (ESSC) is proceeding on the basis of a definition of the Earth system as made up of three major subsystems, the first two quite closely linked, the third somewhat more loosely. They are:
>
> > The fluid subsystem comprising the physical aspects of the atmosphere, ocean, and cryosphere;
> >
> > The biogeochemical cycles comprising the chemical and biological aspects of the entire planet;
> >
> > The solid earth system, including the processes which shape the surface of the earth, and the distribution of minerals and information on past climatic regimes.

An important question in the consideration of the scientific organization of IGBP is how use will be made of (1) existing operational systems, and (2) scientific satellites that are already

either in development or planned. In the first category are the weather satellites operated by NOAA, and in the second category are the NASA research satellites such as the Upper-Atmosphere Research Satellite (already in development) and the oceanography satellite TOPEX (which is into advanced planning). To the extent that such data sources can be used, IGBP could be largely implemented with few new resources. As Dr. Bretherton said, "We have most of the observations systems we are talking about in place already. It is a question of pointing and of supplementing them in ways that will really make them useful for the sorts of problems we are now trying to address." Dr. Bretherton pointed out that a great deal of knowledge comes from data taken daily by the weather services of the world, and the question, then is "can we make them more useful for our purposes?" Dr. Bretherton added that some new systems may be required, but "we should not fall into the trap of thinking that we are talking about a set of observations which are International Geosphere/Biosphere Program just independently of everything else that is going on."

Finally, Dr. Bretherton addressed a very important problem, the relationship of sun and weather. Historically, elucidation of any sun-weather connection has been approached through the investigation of statistical correlations, for example, between the number of sunspots and climate; and these studies have been more or less fruitless, although tantalizing. Dr. Bretherton acknowledged that we are of course dependent on the Sun to warm us, and of course

there are cycles in solar phenomena such as sunspots. Nevertheless, we do not understand completely the relationship between atmospheric phenomena on Earth and the various outputs of the sun "in terms of varying ultraviolet radiation and high-energy particles which are substantial in the lower part of the atmosphere". However, Dr. Bretherton explained that the way to understand how conditions on the Sun relate to effects on the Earth "is by doing good solar physics and understanding solar wind as a phenomenon rather than forcing one's attack on the problem to be very closely related [to predicting the weather]."

In summary, the scientific program of IGBP remains to be defined. NASA through its advisory committee on Earth Systems Sciences, is taking steps to assure that it has a well-defined though broad program which will be a major part of a U.S. national program. Much scientific progress can be made using data from existing sources such as weather satellites.

3. What federal agencies are or should be involved in IGBP? What should they do?

There seemed to be general agreement among the witnesses that the three key agencies in IGBP should be NASA, NOAA, and NSF. Dr. Bretherton also testified that collaboration is expected with the Departments of Defense, Energy, Interior, State, Transportation and Agriculture, and the Environmental Protection Agency.

As mentioned above, NASA cannot assess completely how it will interact with IGBP at this time. However, according to Dr. Tilford, NASA does fully support the broad goals for IGBP. Also, NASA has supported several workshops to help define the scope of IGBP, and it is moving ahead with its own program, "Global Habitability", which would be all or a large part of NASA's contribution to the U.S. national program of IGBP. Dr. Tilford testified that he will give a progress report to the Committee early next year as requested in the report accompanying the Fiscal Year 1985 NASA authorization bill.[11] NASA also intends to continue supporting the IGBP Committee of the National Academy of Sciences.

Dr. Bretherton raised the very interesting question of the relationship between IGBP and NASA's Space Station. IGBP would be a long-term program and the Station would be operative during approximately the same time period. Therefore, the Space Station should be planned to support a very long-term scientific program that would greatly benefit from the availability of integrated Earth observation platform systems. Dr. McElroy made this same point.

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[11]See note 4.

Testifying for NOAA, Dr. McElroy described how that agency "is actively involved in all of the scientific disciplines of the IGBP." Dr. McElroy also described a plethora of international programs in which NOAA is involved and which would interact substantively with IGBP.

Dr. Bridgewater of NSF, in his opening statement described his agency as one that "supports research in response to proposals ... received from the community" and that is therefore very much dependent upon the community. He testified, "We are of course dependent upon proposals that come inhouse." Therefore, since NSF funds proposals based on merit, "the key question for the National Science Foundation is whether the IGBP will encourage first-rate U.S. scientists to prepare first-rate proposals to NSF for study of first-rate scientific problems." Because of this apparently passive role, Mr. Volkmer asked Dr. Malone if he believed the Foundation should be more active. Dr. Malone answered, "I believe [their role] should be an active one." In response to questions, Dr. Bridgewater said that the NSF does support actively the Global Atmospheric Research Program (GARP). Dr. Bridgewater further stated that "an active involvement in major international and interagency activities of this sort ... [is] nothing unusual for us, and we expect to be a full participant in the development of an IGBP." Finally, in response to a direct question from Mr. Volkmer, Dr. Bridgewater testified, "I think that we will be active", in terms of encouraging a planning process.

Dr. Alvin Trivelpiece of DOE testified that everything that involves energy "either comes from or goes back into the ... Earth, and virtually everything we do has some influence on ... the atmosphere and the biosphere." Because of this, the Department of Energy has developed strong in-house research programs of the kind that will be part of IGBP, and Dr. Trivelpiece testified, "We are a generator of the kind of data that will make a contribution to the IGBP and we are also a user of the information that is likely to be generated by it. So, we strongly support it."

In summary, NASA, NOAA, and NSF probably will be the principal agencies in IGBP, but several other agencies should participate in the program as users, data generators, or both. Federal agencies should be cognizant of IGBP in planning future activities.

4. What is the international situation? What needs to be done?

Dr. Malone gave a comprehensive statement of the situation of IGBP internationally as follows:

> "The idea of an international collaborative activity was considered by the Executive Board of ICSU [International Council of Scientific Unions] in Stockholm in January 1983. The decision to explore the feasibility of an international effort was made at a meeting of ICSU's general committee in Warsaw in August 1983. Over the last several months, two dozen scientists from fourteen

different countries have been preparing essays on this concept from their particular disciplinary point of view. These have been gathered together in preprint form and distributed to more than 300 scientists from all over the world who will gather in Ottawa, Canada, on September 25, at an ICSU Symposium on Global Change. This symposium is intended to be the first step in a two-year systematic exploration by ICSU and its constituent bodies of the desirability of actually launching a program currently embraced by the IGBP. The conclusions and recommendations of the symposium will be presented to the General Assembly of ICSU in Ottawa. A decision will then be made whether or not to pursue the development of a scientific strategy during the next two years. This is likely to take the form of a half-dozen workshops addressing themes that are likely to emerge from a Global Change symposium. Participation in these workshops will be drawn from the membership of the twenty scientific unions covering all the disciplines of science and the seventy-one national academies or analogous bodies that constitute ICSU. Since the global observational potential of remote sensing will surely play an important role in any program that may eventually emerge, the involvement of a consortium of national space agencies would be quite appropriate. Similarly, as the scientific directions take shape, it will be desirable to maintain close interaction with the intergovernmental agencies which bring together the

collective strengths of national governments throughout the world. By the time of the next general assembly of ICSU (in 1986), it may be expected that a coherent and pursuasive program could be presented to the world scientific community with some assurance that national governments will look with favor upon implementing the strategy fashioned in this manner. So much for the present status."

Chairman Volkmer questioned Dr. Malone and brought out that ICSU is being used as a vehicle to move toward an organizational structure for IGBP. Dr. Bretherton made the point mentioned above that "unless ... the United States ... can get our act together first, the international efforts will be very, very much harder." Dr. Tilford said essentially the same thing: "without having a strong national program, there is no possibility of developing a strong international program" and the other government agency witnesses agreed with him.

Dr. Bretherton said, "The way you get an international program going on problems of this complexity is to have strong leadership and the U.S. is probably the only country that ... is positioned to take really effective leadership. If we fritter our energies away by essentially not being able to decide internally how to do things, the international program will not be successful."

A related question is why the program must be international, given the fact that national satellites can gather data on a global scale. This was addressed by Dr. Malone who said,

> "Since it is manifestly more simple to mount a national program than it is to fashion an international collaborative effort, it would be tempting to explore the possibility of using satellites to meet the requirement that the program be global in scope. Promising as is the potential for remote sensing to contribute substantially to the proposed program, the observational needs to illuminate complex processes such as the biogeochemical cycling of nitrogen, carbon, sulfur, phosphorus, and water vapor that play such an important role in linking together the ocean, atmosphere, earth, and biota (as well as being essential to nourish all forms of life) make necessary in situ observations. Moreover, even the best remote-sensed observations require "ground truth" for validation. Finally, if the knowledge gained through such an endeavor is to find practical utility in the management of the biosphere during the next century, it is essential that participation in the acquisition of that knowledge base involve all nations who will be concerned with putting in place policies for managing the biosphere."

In subsequent questioning, Dr. Malone made clear that not all of the processes that would be studied in IGBP can be studied from satellites. Dr. Bretherton also addressed this question in the following way:

> "A proper international basis for such an enterprise is necessary for at least three reasons. For many of the essential variables, observations can only be made and data exchanged with the active collaboration of the nations within whose territory or economic zone they are required. These observations are often made primarily for other purposes and the cost of the U.S. duplicating the entire system would be prohibitive even if technically feasible. Finally (and personnally I find this reason the most compelling), the purpose for improved understanding of the system is to enable more intelligent actions on problems of global concern. Without active participation by both scientists and governments from around the world in the process of establishing that understanding it is unlikely to influence their actions."

Dr. Bretherton enlarged upon this, saying that the scientific strategy for IGBP "calls for a blend of detailed in situ observations at carefully preserved test sites in all the major climatic and soil regimes of the world, coupled with the use of remote sensing to determine the spatial extent of the biomes represented by those sites. These sites will have to be in many different

countries ..." Dr. Bretherton also pointed out that this international access will have to be maintained for the several decades that the program will run.

Dr. Malone argued that since "two-thirds of the world scientists [are] resident [outside] the United States, it is evident that a collaborative effort not only is desirable, but is necessary." He also pointed out that the world's greatest expert on biochemical cycles is in Sweden and, on sulfur, in Russia.

Several witnesses mentioned other international science programs, including the World Climate Program, the Global Environmental Monitoring System, the Middle Atmosphere Program, the International Satellite Cloud Cover Program, and many others. Dr. McElroy, in particular, described a host of such programs. In view of the many existing international programs, Chairman Volkmer questioned whether we really need the IGBP, and if we do need it, how it should interact with these other programs. Dr. Malone answered that, "Yes, we do need another program, and its focus should be on the interaction of these programs, and not replacing these programs. In other words, what we need is something which will develop a synthesis and view this system in a holistic sense ... I think the key word is interact." He went on to say that the IGBP should be the means by which the other programs interact and Dr. Bretherton agreed.

Dr. Malone stated that the atmosphere, the oceans, the Earth, and the solar-terrestrial domain and life within the biosphere are all linked and that research in these areas has made a great deal of progress, but because of the importance of the links, "it is my judgement that progress in each of these five fields will plateau unless we look at the system as a whole." He went on to describe other reasons as to why IGBP is timely. His reasons were as follows: First, there are attractive scientific problems in IGBP. Second, the technology is now available. Third, the emergence of global anthropogenic changes in the environment require study to ensure that we don't make irreversible adverse changes. And fourth, we are now moving into an era in which population growth will strain our natural resources, particularly in the developing countries, and we need to understand that situation.

Dr. Tilford described the "unique contribution" of IGBP as the inclusion of the biosphere. He went on to say, "Most of the other worldwide programs now have to do with physical phenomena ... I don't believe that any of these programs have taken into consideration the biogeochemical cycles ... this is the one thing which ties the whole system -- the Earth -- together."

Dr. McElroy pointed out another advantage of carrying out a program like IGBP. Based on his knowledge of IGY, "once the scientists start thinking of this earth systems model, begin to approach it from that perspective, there are certain things which just fall into place." In other words, there will be benefits

from the program, because scientists will begin to think about the links between the various areas, the atmosphere, the oceans, et cetera, even without necessarily having organized coordination.

Dr. Bretherton mentioned one specific example of an issue needing study: We are putting active nitrogen into the Earth system at a much higher rate that twenty years ago, due to our use of fertilizer. "That has ramifications through the chemistry of the atmosphere up to the ozone cycle in the stratosphere through all sorts of things including ultimately the climate ... that we are just beginning to see." And this involves things such as the bacteria in the Earth, which can change the nitrogen cycle.

In summary, IGBP must be international because of a need for "ground-truth" and the need for the participation of many scientists in different parts of the world. IGBP will provide for the interaction of many existing but scientifically narrower international programs and will add the biological component presently missing from such studies.

5. What practical benefits could flow from knowledge gained through IGBP?

The Subcommittee did not receive crisply focused testimony on this question. The immediate benefit from IGBP will be a better understanding of the Earth and the practical benefits will accrue later, e.g., as Dr. Malone testified, "in the management of the bio-

sphere in the next century." Because we have learned that all its parts are connected the IGBP will study the Earth-as-a-system, and the understanding gained might be qualitatively new. For this reason, we may see qualitatively different benefits, for example, much better weather and climate predictions. However, it is important to realize that these benefits lie somewhere in the future. For example, Dr. Bridgewater testified, "The results of GARP (Global Atmospheric Research Program) convinced many scientists in the U.S. and other countries that international research and technological capabilities would permit, in the late 1980s and 1990s, comprehensive studies of the global atmosphere and ocean that would provide a basis for later development of predictive capabilities for global climate."

Dr. Bretherton pointed out the specific kinds of problems that could be dealt with based on a new understanding: "The climate changes to be expected from the worldwide consumption of fossil fuels, the sensitivity of the stratospheric ozone to trace gases such as fluorocarbons, the causes of past extinctions of whole classes of living species -- these are questions of fundamental importance that can only be addressed from a global, interdisciplinary perspective, drawing on a wide range of observations and skills quite beyond the range of any one individual or institution. And further, "the theme [of IGBP] is the earth as a functional system, emphasizing primarily the fundamental understanding which must underlie intelligent handling of the many environmental issues which have arisen in recent years and will continue to

arise, rather than specific issues themselves. At the same time, the expectation remains that in due course, this fundamental understanding is likely to contribute" to the solution of these more immediate problems.

Dr. Trivelpiece testified of several interests of the Department of Energy. For example, DOE is interested in the effects of increasing carbon dioxide in the atmosphere, and has its own research program addressing this. DOE is also very much interested in the disposal of waste from nuclear plants and the siting of such plants. The Department is also interested in and conducting research on the fate and transport of emissions from fossil fuel burning plants. Testimony shows that there are a great many potential benefits in the IGBP program, although it will take time for them to be realized.

In summary, although the Committee had requested it, no testimony described specific, immediate, practical benefits to be expected from the program, but all witnesses were confident that a better understanding of the Earth as a system will have significant payoffs in the future.

6. Should or could IGBP begin with an attempt to develop an integrated, coordinated (but probably not centralized) data system?

The witnesses agreed that data management will be critical. For example, Dr. McElroy testified that, "A key element in the success of the IGBP will be the ability to manage the collection, processing, distribution and archiving of a tremendous amount of data." And Dr. McElroy also identified the data management problem as, "quite possibly the most significant challenge in IGBP". Dr. Trivelpiece characterized this challenge more vividly as "how to ignore about 50 percent of the data". Dr. Tilford testified that a NASA Advisory Committee on Earth Observations recommended that, "a data system that provides easy, integrated and complete access to past, present, and future data must be developed as soon as possible." He also testified that NASA believes "that work should begin now to explore requirements for the future interactive global resource information system."

Chairman Volkmer asked whether the IGBP would be the manager of this data system or whether each national group would manage their own system. Dr. Malone testified that he believed that "national management will be the answer. It was the answer in the IGY --

World Data Center A and B -- it worked extremely well." Dr. Bretherton added that "what is essential is the international agreement that facilitates exchange between those national structures."

The Chairman specifically questioned whether there would be need for a "centralized data bank system". Dr. Bretherton testified that most of the data would be decentralized although there would be some centralized data, but he said that he could not give a precise answer to such a question at this time. Dr. Tilford made a very similar point when he testified, "I don't see a large centralized data base, but I do see a number of distributed data bases with connecting facilities and communications such that people can have access to them, which has not been the case in many examples that we had in the past." Dr. Malone suggested that there is a control mechanism to keep us from drowning in data and that is "to insist that data collection be aimed at resolving a specific scientific problem."

Dr. Tilford went on to suggest that ICSU could provide scientific leadership in this matter. He also testified that NASA has signed an agreement with UNEP to establish and demonstrate a Global Resource Information Database (GRID).

In summary, there was no testimony that either ICSU or IGBP should manage a data system, but there was a great deal of testimony that the data system will need management. Thus, how the data will be

managed remains very much an open question, although NASA is taking some steps to demonstrate a pilot system.

7. Is there a need for Congressional action, and if so, what?

The Committee was not contemplating taking action when these hearings were planned. The hope was simply to learn the status of this program and to encourage the responsible agencies to participate in and to lend support to IGBP. However, Dr. Bretherton testified that he represents "a group which is trying to build a consensus within both the scientific community and in the relevant agencies towards a strong U.S. national effort in this area, and we would appreciate indeed any guidance or comments that you would care to give us in the course of our activities." Dr. Malone urged "a blend of patience and constant interaction with the process on the part of Congress as the program unfolds." He went on to say, "At that moment in time when you [the Congress] are satisfied that the planning is sound, and the execution feasible, a concurrent resolution would be of enormous value."

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